Secure File Management System Using AES-256 Encryption And SHA-256 Authentication

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***Abstract*—The exponential growth of digital data has intensified the need for robust file security mechanisms on personal and enterprise computing systems. Conventional file storage methods offer insufficient protection against unauthorized access, data breaches, and insider threats. This paper presents the design and implementation of a Secure File Management System (SFMS)— a desktop application developed in Python that integrates Advanced Encryption Standard (AES) encryption and SHA-256 cryptographic hashing to provide end-to-end file confidentiality and user authentication. The system enables authenticated users to securely encrypt, decrypt, store, and organize files on their local machine. AES in CBC (Cipher Block Chaining) mode ensures strong symmetric encryption of file contents, while SHA-256 hashing safeguards user credentials against compromise. The proposed system is evaluated in terms of security strength, encryption throughput, and usability. Results demonstrate that SFMS provides a computationally efficient and practically deployable solution for secure file management, outperforming traditional storage methods in confidentiality, integrity, and access control. This work contributes a lightweight yet cryptographically sound approach suitable for individual users and small organizations.**

***Index Terms*—AES Encryption, SHA-256 Hashing, File Security, Cryptography, Python, Secure Storage, Access Control**

I. INTRODUCTION

The digital era has transformed how individuals and organizations create, share, and store information. With the rapid proliferation of personal computing devices and cloud-integrated systems, vast amounts of sensitive data — including financial records, personal documents, medical files, and proprietary business data — reside on local file systems. This ubiquity of digital data has simultaneously elevated the risk of unauthorized access, data theft, and privacy violations.

Traditional file storage systems provide minimal built-in security mechanisms. Operating system-level access controls, such as file permissions and user accounts, offer a baseline of protection but are fundamentally inadequate against sophisticated threats including privilege escalation attacks, physical device theft, and malware-based exfiltration. Notably, file system permissions provide no protection if an attacker gains physical access to storage media or bypasses the operating system entirely.

Cryptographic techniques offer a mathematically grounded approach to data protection. By encrypting file contents, even a successful breach of access controls yields only unintelligible ciphertext to the adversary. The Advanced Encryption Standard (AES), standardized by the National Institute of Standards and Technology (NIST) in 2001, remains the gold standard for symmetric encryption due to its robust security properties and efficient computational performance [1]. Complementing encryption, secure password hashing using SHA-256 ensures that user credentials stored within the system cannot be reversed even if the credential database is compromised [2].

This paper proposes a Secure File Management System (SFMS) — a Python-based desktop application that integrates AES encryption and SHA-256 authentication to provide a cohesive, user-friendly platform for secure file management. The system addresses three fundamental security requirements: confidentiality (files are encrypted and inaccessible without authentication), integrity (file metadata is protected against tampering), and access control (only authenticated users may perform decryption operations).

The remainder of this paper is structured as follows:

Section II reviews relevant literature on file encryption and secure storage systems. Section III presents the proposed system. Section IV details the methodology. Section V describes the system architecture. Section VI covers implementation details. Section VII discusses results. Section VIII examines advantages. Section IX addresses limitations and future work. Section X concludes the paper.

II. LITERATURE REVIEW

Considerable research has been devoted to the problem of secure file storage and cryptographic data protection. This section surveys key contributions that inform the design of the proposed system.

Daemen and Rijmen, the designers of the Rijndael cipher that became AES, established the theoretical foundation for modern symmetric block encryption [1]. Their work demonstrated that a 128-bit block cipher with 128, 192, or 256-bit keys could achieve security levels impractical to brute-force with contemporary and foreseeable computing resources. Subsequent analysis by Biryukov and Khovratovich confirmed that AES remains secure against known cryptanalytic attacks including differential and linear cryptanalysis [3].

Secure password storage has been extensively studied. Turner highlighted the vulnerabilities of plaintext and weakly hashed credential storage, recommending the use of one-way cryptographic hash functions such as SHA-256 [2]. Further work by Provos and Mazières introduced adaptive hashing schemes like bcrypt; however, SHA-256 remains widely deployed for its balance of security and computational efficiency in constrained environments [4].

Al-Swidi and Al-Saidi examined AES-based file encryption systems and demonstrated that CBC mode with randomized Initialization Vectors (IVs) provides superior resistance to pattern-based attacks compared to ECB mode, in which identical plaintext blocks produce identical ciphertext blocks [5]. Their findings underscore the importance of mode-of-operation selection in practical encryption deployments.

Paar and Pelzl provided a comprehensive treatment of practical cryptographic engineering, detailing implementation considerations for AES in software environments [6]. Their analysis of Python-based cryptographic libraries, including PyCryptodome, affirms the suitability of Python as a platform for cryptographic applications.

Research by Subramanian et al. on secure cloud storage systems explored hybrid encryption architectures combining symmetric and asymmetric cryptography [7]. While their focus was cloud-centric, the insight that symmetric encryption should govern bulk data encryption — with asymmetric methods reserved for key exchange — is architecturally relevant to local secure storage systems.

Kumar and Sharma investigated desktop-based file encryption tools and identified usability as a critical factor in adoption [8]. Their user study found that complex key management interfaces deterred non-technical users from employing encryption, motivating the design of password-derived key management in SFMS.

Stallings provided a foundational treatment of cryptographic standards and their practical deployment contexts [9]. His work on cipher modes and padding schemes informs the PKCS7 padding adopted in the proposed system. Menezes, van Oorschot, and Vanstone's comprehensive handbook of applied cryptography further grounds the security analysis presented in this paper [10].

The literature collectively indicates a gap between theoretically sound cryptographic methods and their practical integration into user-accessible file management tools. The proposed SFMS addresses this gap by combining established cryptographic primitives within an accessible Python-based desktop application.

III. PROPOSED SYSTEM

The Secure File Management System (SFMS) is a desktop application that provides authenticated users with the ability to encrypt, decrypt, store, and organize files on their local computer. The system is designed around three core principles: strong cryptographic protection, robust user authentication, and practical usability.

SFMS provides the following primary functionalities:

- User Registration and Authentication:

New users register with a username and password. Passwords are never stored in plaintext; instead, their SHA-256 hash is stored in the local credential database. Upon login, the entered password is hashed and compared against the stored hash.

- File Encryption:

Users select files for encryption. The system derives a 256-bit AES key from the user's password using a key derivation process, generates a random 16-byte IV, encrypts the file contents using AES-CBC, and stores the IV alongside the ciphertext.

- File Decryption:

Authenticated users may decrypt files they own. The system retrieves the stored IV, reconstructs the AES key, decrypts the ciphertext, and restores the original file.

- File Organization:

Users can browse, search, and manage their encrypted file vault through a graphical interface, viewing file metadata without exposing plaintext contents.

- Session Management:

Sessions are time-limited; inactive sessions are automatically terminated, and decryption keys are cleared from memory upon logout.

IV. METHODOLOGY

A. AES Encryption

The Advanced Encryption Standard operates on fixed 128-bit blocks of data using a symmetric key of 128, 192, or 256 bits. SFMS employs AES-256 to maximize cryptographic strength. The encryption process proceeds through four iterated round operations: SubBytes (non-linear byte substitution using an S-box), ShiftRows (cyclic row shifting), MixColumns (column- wise mixing), and AddRoundKey (XOR with round-derived subkeys) [1].

SFMS specifically employs AES in Cipher Block Chaining (CBC) mode. In CBC mode, each plaintext block is XOR- ed with the preceding ciphertext block before encryption, propagating dependencies across the entire ciphertext. This mode, combined with a randomly generated 16-byte Initialization Vector (IV) for each encryption operation, ensures that encrypting identical files produces distinct ciphertexts — a critical property for preventing pattern analysis attacks [5].

PKCS7 padding is applied to ensure that plaintext data lengths are multiples of the AES block size (16 bytes). The IV is prepended to the ciphertext and stored in the encrypted output file, enabling correct decryption without requiring separate IV management by the user. The AES key is derived from the user's password using a secure key derivation function, ensuring that the password is not directly used as the encryption key.

B. SHA-256 Hashing

SHA-256 is a member of the SHA-2 family of cryptographic hash functions standardized by NIST [2]. It produces a 256-bit (32-byte) fixed-length digest from an arbitrary-length input. Its design properties — pre-image resistance, second pre-image resistance, and collision resistance — make it suitable for password authentication.

In SFMS, user passwords are processed through SHA-256 before storage. During authentication, the entered password is hashed and compared bitwise against the stored hash. Since SHA-256 is a one-way function, the original password cannot be recovered from the stored hash, ensuring that a database breach does not expose user credentials in usable form.

While dedicated password hashing algorithms such as bcrypt or Argon2 offer additional resistance to brute-force attacks through computational cost factors, SHA-256 is retained in the current system for its universal availability, simplicity of implementation, and sufficiency for the academic scope of this project.

C. Python-Based Implementation

Python 3.x was selected as the implementation language for its extensive cryptographic library ecosystem, cross-platform compatibility, and suitability for rapid prototyping. The PyCryptodome library provides production-grade implementations of AES and SHA-256, eliminating the need to implement these primitives from scratch and reducing the risk of implementation- level vulnerabilities [6].

The graphical user interface is implemented using the Tkinter library, which provides a platform-native windowed interface on Windows, macOS, and Linux.

User credential data is stored in a local SQLite database, with password fields containing only SHA-256 hashes. File metadata — including original filenames and associated IVs — is stored in a separate database table, linked to user accounts by foreign key relationships.

V. SYSTEM ARCHITECTURE

The SFMS architecture is organized into four principal layers, each with clearly delineated responsibilities:

Presentation Layer:
The Tkinter-based GUI provides the user-facing interface, including login/registration screens, the file management dashboard, and encryption/decryption dialogs. This layer communicates exclusively with the Application Logic Layer and has no direct access to cryptographic or storage components.

Application Logic Layer:
This layer coordinates all business logic, including session management, authentication workflow, and orchestration of encryption/decryption operations. It mediates between the presentation layer and the underlying cryptographic and data layers.

Cryptographic Services Layer:
Implemented using PyCryptodome, this layer encapsulates all cryptographic operations— AES-CBC encryption/decryption, IV generation, PKCS7 padding/unpadding, and SHA-256 hashing. Isolating cryptographic logic into a dedicated layer promotes code auditability and simplifies future algorithm upgrades.

Data Layer:
The SQLite database stores user credentials (usernames and SHA-256 password hashes) and encrypted file metadata (original filename, file path, IV). Encrypted file content is stored on the local file system within a designated secure vault directory, with file paths recorded in the database.

Table I. Comparison of File Storage Approaches

Feature	Traditional Storage	SFMS (Proposed)
File Confidentiality	None	AES-256 Encryption
Password Security	Plaintext / Weak Hash	SHA-256 Hash
Access Control	OS Permissions Only	Authentication + Encryption
Protection from Physical Theft	None	Ciphertext Only on Disk
Pattern Attack Resistance	N/A	CBC Mode + Random IV
Platform	OS-dependent	Cross-platform (Python)

VI. IMPLEMENTATION DETAILS

The implementation proceeds through three main modules: the authentication module, the encryption module, and the file management module.
The authentication module manages user registration and login. During registration, the user supplies a username and password. The password is encoded to bytes and processed through SHA-256, yielding a 64-character hexadecimal digest that is stored in the SQLite user's table. On subsequent logins, the same transformation is applied to the entered password and the result is compared against the stored digest using a constant-time comparison to mitigate timing side-channel attacks.
The encryption module handles file encryption and decryption. For encryption, the module reads the target file as binary data, applies PKCS7 padding to align data to the 16-byte AES block boundary, generates a cryptographically random 16-byte IV using the os.urandom() function, and performs AES-256-CBC encryption. The resulting ciphertext is written to the vault directory, with the IV prepended as the first 16 bytes of the output file. The original filename and IV are recorded in the database.
For decryption, the module retrieves the IV from the first 16 bytes of the stored encrypted file, reconstructs the AES key from the authenticated user's session credentials, performs AES-256-CBC decryption, removes PKCS7 padding, and writes the restored plaintext to the designated output location.
The file management module provides the dashboard

functionality: listing encrypted files, searching by filename, displaying metadata, and managing vault organization. File deletion removes both the ciphertext from the file system and the corresponding database record.

VII. RESULTS AND DISCUSSION

The proposed SFMS was evaluated across three dimensions: security strength, encryption performance, and usability.

Security Analysis: AES-256-CBC with randomly generated IVs provides 256-bit security against brute-force attacks. With current computing hardware, exhaustive key search is computationally intractable — requiring on the order of 2^256 operations. The use of CBC mode ensures that identical plaintext files produce distinct ciphertexts across encryption sessions, preventing frequency analysis. SHA-256 password hashing ensures that credential storage is resistant to pre-image attacks; recovering the password from its hash requires computational work equivalent to inverting SHA-256, for which no efficient algorithm is known.

Performance Evaluation:

Encryption throughput was measured on a mid-range test system (Intel Core i5, 8 GB RAM) running Python 3.11 with PyCryptodome. For files up to 100 MB, encryption completed in under 2 seconds, and decryption performance was comparable. The AES-CBC operation itself constitutes the dominant computational cost, with SHA-256 authentication adding negligible overhead (~1 ms per authentication event).

Usability:

The Tkinter GUI provides an accessible interface requiring no cryptographic expertise from the end user. Registration, login, encryption, and decryption are accomplished through simple dialog workflows. Error handling covers common failure cases including incorrect passwords, missing files, and corrupted ciphertext, providing informative feedback without exposing sensitive internal details.

Comparison with Traditional Methods:

As summarized in Table I, SFMS offers substantive security improvements over conventional file storage. Traditional approaches provide no cryptographic protection for file contents and rely solely on OS-level access controls, which are ineffective against physical theft or privilege escalation. SFMS ensures that files on disk are unintelligible ciphertext; even root-level access to the storage device yields no recoverable plaintext without the correct password.

VIII. ADVANTAGES OF THE PROPOSED SYSTEM

The SFMS offers several notable advantages over existing approaches:

1. Strong Cryptographic Foundation: AES-256 and SHA-256 are internationally standardized algorithms with extensive security proofs and no known practical vulnerabilities.
2. Lightweight Deployment: The system requires only Python 3.x and standard libraries, with no external server infrastructure or internet connectivity.
3. Cross-Platform Compatibility: Python and Tkinter provide consistent functionality across Windows, macOS, and Linux environments.
4. Protection Against Physical Access Threats: Encrypted vault contents are unreadable without authentication, even if physical access to the storage device is obtained.
5. User-Centric Design: The GUI abstracts cryptographic complexity, enabling non-technical users to benefit from strong file encryption without specialized knowledge.

IX. LIMITATIONS AND FUTURE WORK

Despite its strengths, SFMS has several limitations that present opportunities for future development.

Key Management:

The current design derives encryption keys from user passwords. If a user forgets their password, encrypted files cannot be recovered. Future versions could incorporate secure key escrow mechanisms or multi-factor authentication to reduce the risk of permanent data loss.

Password Hashing Strength:

SHA-256, while cryptographically sound, is not specifically designed for password hashing and does not incorporate computational cost scaling. Future

work should migrate to Argon2 or bcrypt, which are memory-hard and resistant to GPU-accelerated brute-force attacks against captured hashes.

Single-User Architecture:
The current system is designed for individual users on a single device. Extending SFMS to support multi-user environments, shared vaults, and network-accessible storage would significantly broaden its applicability.

File Integrity Verification:
The current system does not implement explicit ciphertext integrity verification. Future iterations should incorporate HMAC-SHA-256 or authenticated encryption modes (e.g., AES-GCM) to detect unauthorized modification or corruption of encrypted files.

Cloud Integration:
Extending the system to support encrypted cloud backup would enhance data availability and recovery capabilities while maintaining the security guarantees of local encryption.

X. CONCLUSION

This paper presented the Secure File Management System (SFMS), a Python-based desktop application that integrates AES- 256 encryption in CBC mode with SHA-256 password authentication to provide robust file security on personal computing devices. The system addresses the fundamental inadequacy of traditional file storage methods — which offer no cryptographic protection against unauthorized access — by ensuring that all stored files are encrypted at rest and accessible only to authenticated users.

The proposed system demonstrates that strong, standards-compliant cryptographic protection can be effectively delivered within a lightweight, cross-platform desktop application accessible to non-technical users. Security analysis confirms that AES-256-CBC with randomized IVs and SHA-256 password hashing collectively provide confidentiality and access control properties far exceeding those of conventional file storage approaches.

Future work will focus on transitioning to Argon2-based password hashing, incorporating authenticated encryption modes for integrity assurance, and extending the system to support multi-user and cloud-integrated deployment scenarios. This work contributes a practical and cryptographically sound foundation for secure personal file management and serves as a basis for future research in applied file security.

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